Poorman's Electric Harmonica Warmer 1-1

(PEHW 1-1)

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1. INTRODUCTION.

Exhaled air from the lungs is saturated with water. It's relative humidity is close to (or maybe equal to) 100 percent, and the temperature of the exhaled air is close to (or maybe equal to) the normal body temperature of 37 degrees Celsius.

Air at 35 degrees Celsius can hold 39.6 grams of water per cubic meter.
Air at 25 degrees Celsius can hold 23.0 grams of water per cubic meter.

This means that if a cubic meter of air at 100% relative humidity is cooled down from 35 to 25 degrees Celsius, then 39.6 - 23.0 = 16.6 grams of water will condense out of the air.

Tidal volume. -- Tidal volume is the volume of air that is transported into and out of the lungs with each respiratory cycle. In a healthy human adult male, tidal volume is approximately 500 mL, and in a healthy human adult female it is approximately 400 mL.

Respiration rate. -- Normal respiration rate is 12 to 20 breaths per minute. Let's use 16 breaths per minute which is halfway between 12 and 20 breaths per minue. At 500 mL per breath, that is 8 litres per minute of air. In 7.5 minutes that is 60 litres of air. 16.6 x 60 / 1000 = 1 gram of water that condenses out of your breath after 7.5 minutes of playing. 1 gram of water = 1 mL = 1 cubic centimetre = 1/5 teaspoon.

Prevention. -- To prevent the water from codensing all you have to do is heat up the harmonica to about 37 degrees Celsius so it is at or above the temperature of the air leaving your lungs.

Table 1-1. Harmonicas that I have modified with the PEHW 1-1

	Manufacturer	Model	Size	Weight	Resistor Value	Resistor Size Code
1	Suzuki	Chromatix SCX 48	12 holes	235 grams	39.9 ohms	2010
2	Suzuki	Chromatix SCX 56	14 holes	262 grams	39.9 ohms	2010
3	Suzuki	Chromatix SCX 64	16 holes	288 grams	39.9 ohms	2010
4	Suzuki	Sirius S-56S	14 holes	364 grams	34.0 ohms	2512
5	Suzuki	Sirius S-64C	16 holes	392 grams	39.9 ohms	2010
6	Hohner	CX-12 7545T	12 holes	185 grams	39.9 ohms	2010
7	Seydel	DE LUXE	12 holes	198 grams	39.9 ohms	2010
8	Seydel	Saxony	12 holes	268 grams	39.9 ohms	2010

Effect on sound. -- The PEHW 1-1 adds a small amount of weight to the reed plates which will lower the resonant frequency of the reed plates. Any change in sound is not noticeable to my ears. If you pour a cup of water into a swimming pool, how much does the water level go up?

1.1. Harmonica comb sizes.

1.2. Acronyms and abbreviations.

mAh	milliampere hour
mL	millilitre (1 cubic centimetre)
PEHW	Poorman's Electric Harmonica Warmer

Qty	Quantity
UOM	Unit Of Measure

1.3. Disclaimer.

1.4. Revision history.

Table 1-2. Revision history.

Date	Description
2022-Nov-01	Preliminary (draft) version

2. THEORY OF OPERATION.

2.1. Thick film chip resistors.

Thick film chip resistors are small surface mount resistors that are used in almost all modern electronic devices such as personal computers, cell phones, and tablets. They are a bit exotic in that you will not find them for sale individually at Home Depot. The manufacturers sell these on reels that each contain 1,000 or more resistors. They can be ordered online in small quantities from distributors such as Digi-Key and Mouser.

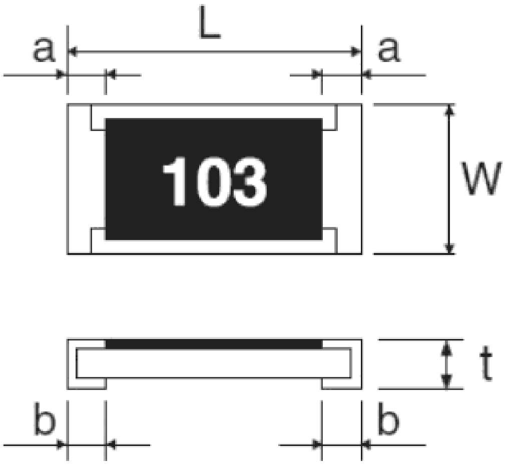


Figure 2-1. Thick film chip resistor dimensions

Table 2-1. Resistor size codes

Size Code	Length (L)	Width (W)	Thickness (t)	Rated Power
2010	0.20 inch	0.10 inch	0.02 inch	0.75 watts
2512	0.25 inch	0.12 inch	0.02 inch	1.00 watts

Table 2-2 shows the amount of power dissipated by different resistor values that are driven by 5V USB power. There is one resistor on each reed plate, and there are two reed plates in the harmonica, so there are two resistors in the harmonica which means that the total current and power are equal to two times the values shown in the table. The resistance values are chosen to produce about 0.05 watts per hole in the harmonica for one resistor. The following equations can be used to calculate the current flowing through each resistor and the power dissipated in each resistor.

$$V = R \times I$$
$$P = V \times I$$

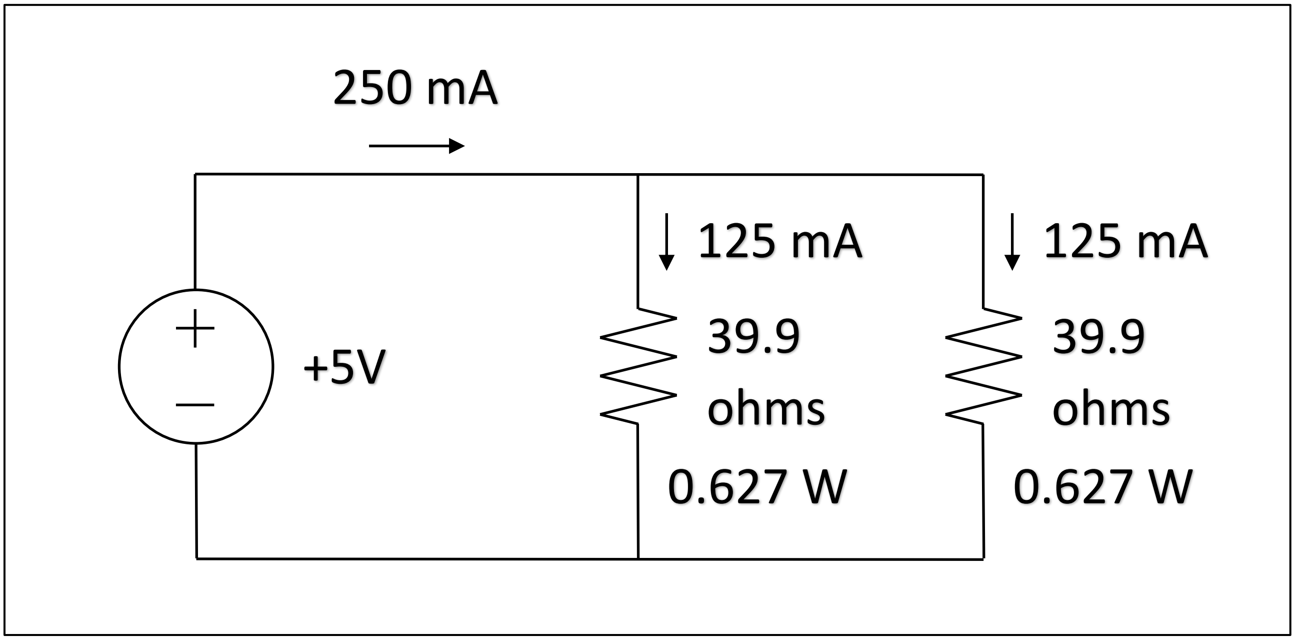
Table 2-2. Resistor values

Size Code	Resistance (R)	Rated Power	Voltage (V)	Current (I)	Actual Power (P)	Harmonica Size	Power per Hole (for one resistor)
2010	39.9 ohms	0.75 watts	5 volts	0.125 A	0.627 watts	12 holes	0.0523 watts/hole
2010	39.0 ohms	0.75 watts	5 volts	0.128 A	0.641 watts	12 holes	0.0534 watts/hole
2512	34.0 ohms	1.00 watts	5 volts	0.147 A	0.735 watts	14 holes	0.0525 watts/hole
2512	29.4 ohms	1.00 watts	5 volts	0.170 A	0.850 watts	16 holes	0.0531 watts/hole

Table 2-3. Resistor part numbers

Manufacturer	Part No.	Description	Digi-Key Part No.
TE	CRGCQ2010F39R	39.0 ohms +/-1% 0.75W 2010	A129915CT-ND
Rohm	MCR100JZHF34R0	34.0 ohms +/-1% 1.00W 2512	RHM34.0BBDKR-ND
Rohm	MCR100JZHF29R4	29.4 ohms +/-1% 1.00W 2512	RHM29.4BBCT-ND

2.2. Circuit diagram.



2.3. Battery life.

Table 2-4 lists the expected life of a typical 5V battery.

Table 2-4. Battery life.

	Battery Energy Capacity	Resistor Value	Current (2 resistors)	Expected Battery Life
1	5,200 mAh	39.9 ohms	250 mA	20.8 hours
2	5,200 mAh	34.0 ohms	294 mA	17.7 hours
3	5,200 mAh	29.4 ohms	340 mA	14.3 hours

2.4. Hohner CX-12.

The Hohner CX-12 is notoriously difficult to warm up because the outer plastic body is a fairly good thermal insulator compared to the metal cover plates that are normally used on harmonicas. The insulating effect of the outer plastic body improves the operation of the PEHW 1-1 because it reduces the amount of heat that flows through the reed plates.

3. PARTS AND TOOLS.

Table 3-1. Parts list.

	Description	Manufacturer	Qty	UOM
1	Original Cold-Weld Formula epoxy	J-B Weld	2	mL
2	Surface mount resistors		2	each
3	JST PH 2-mm pitch 2-pin top-entry through-hole header connector	J.S.T. Mfg. Co., Ltd.	2	each
4	JST PH 2-mm pitch housing and contact	J.S.T. Mfg. Co., Ltd.	2	each
5	USB 2.0 cable		1	each
6	USB battery pack		1	each

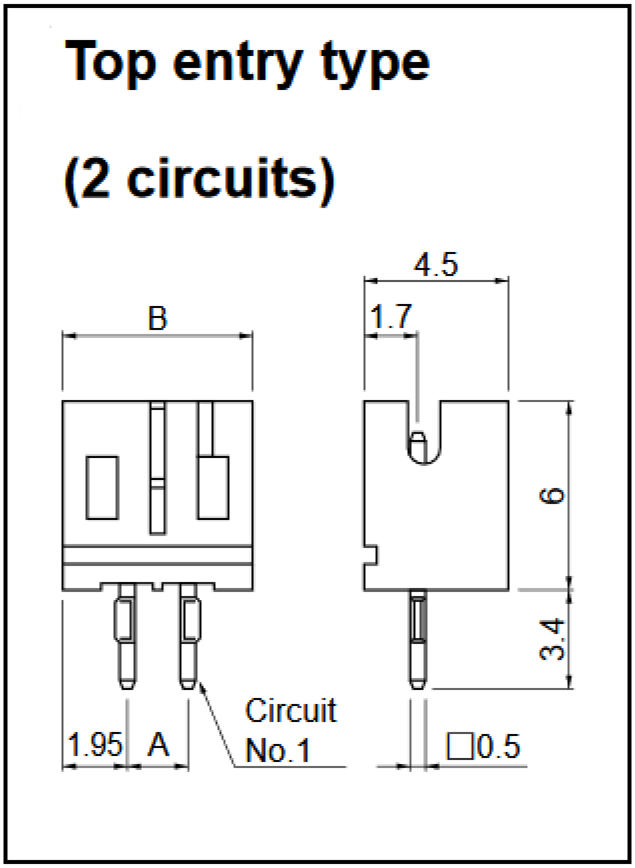
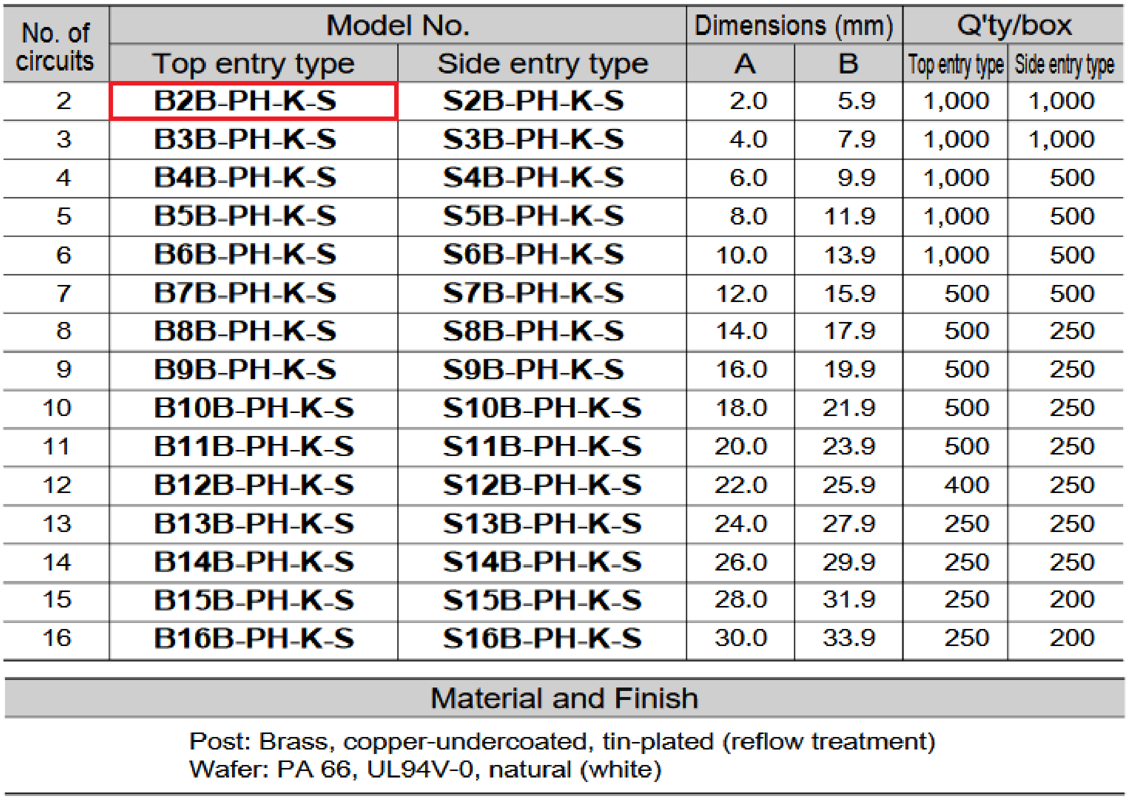


Figure 3-1. JST PH connector drawing.

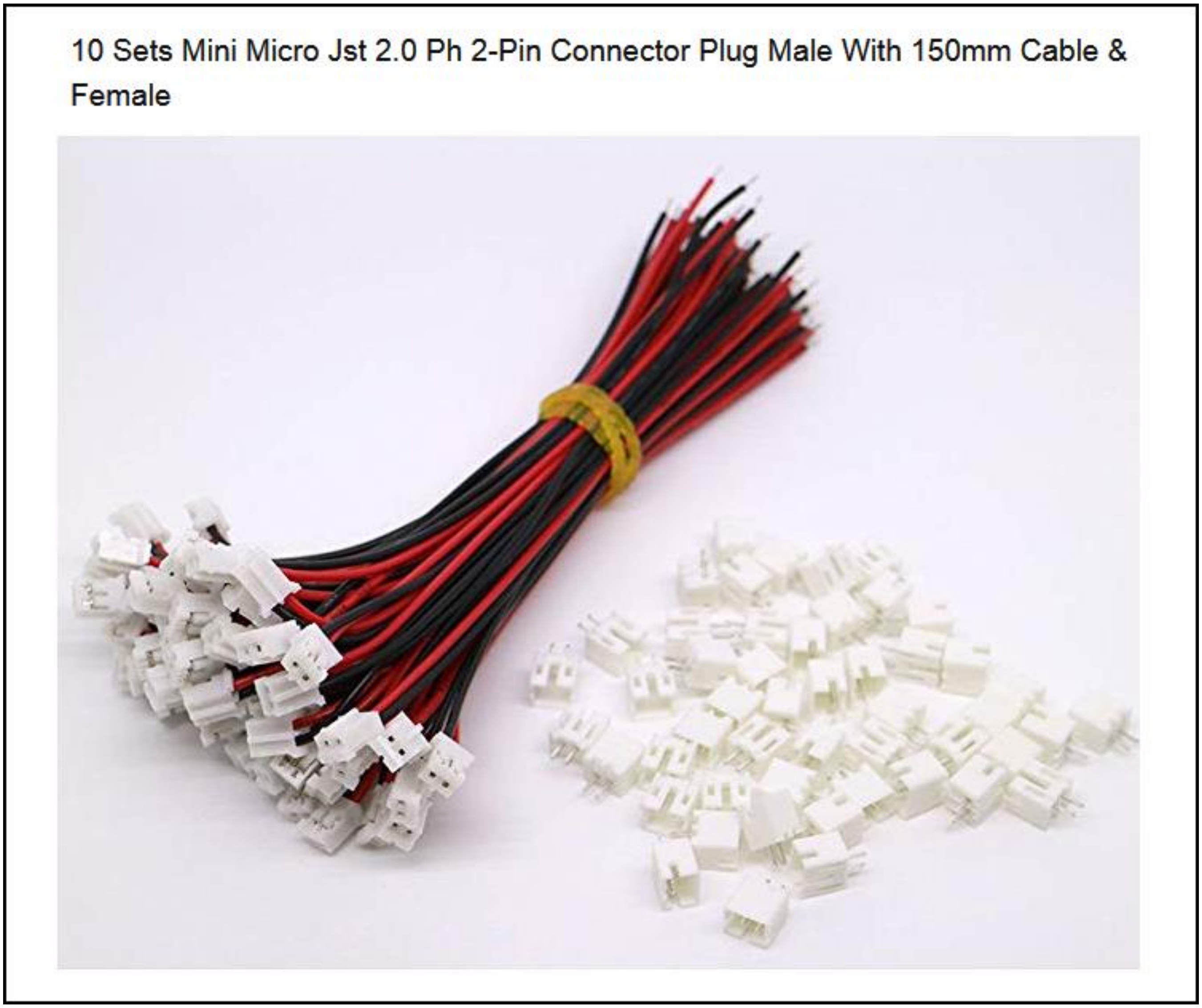


No. of circuits	Model No.		Dimensions (mm)		Q'ty/box	
	Top entry type	Side entry type	A	B	Top entry type	Side entry type
2	B2B-PH-K-S	S2B-PH-K-S	2.0	5.9	1,000	1,000
3	B3B-PH-K-S	S3B-PH-K-S	4.0	7.9	1,000	1,000
4	B4B-PH-K-S	S4B-PH-K-S	6.0	9.9	1,000	500
5	B5B-PH-K-S	S5B-PH-K-S	8.0	11.9	1,000	500
6	B6B-PH-K-S	S6B-PH-K-S	10.0	13.9	1,000	500
7	B7B-PH-K-S	S7B-PH-K-S	12.0	15.9	500	500
8	B8B-PH-K-S	S8B-PH-K-S	14.0	17.9	500	250
9	B9B-PH-K-S	S9B-PH-K-S	16.0	19.9	500	250
10	B10B-PH-K-S	S10B-PH-K-S	18.0	21.9	500	250
11	B11B-PH-K-S	S11B-PH-K-S	20.0	23.9	500	250
12	B12B-PH-K-S	S12B-PH-K-S	22.0	25.9	400	250
13	B13B-PH-K-S	S13B-PH-K-S	24.0	27.9	250	250
14	B14B-PH-K-S	S14B-PH-K-S	26.0	29.9	250	250
15	B15B-PH-K-S	S15B-PH-K-S	28.0	31.9	250	200
16	B16B-PH-K-S	S16B-PH-K-S	30.0	33.9	250	200

Material and Finish

Post: Brass, copper-undercoated, tin-plated (reflow treatment)
Wafer: PA 66, UL94V-0, natural (white)

Figure 3-2. JST PH connector part number



10 Sets Mini Micro Jst 2.0 Ph 2-Pin Connector Plug Male With 150mm Cable & Female

Figure 3-3. JST PH connector header and socket as seen on Amazon.

Table 3-2. Tools and supplies.

	Description	Manufacturer	Part No.
1	Soldering iron	Hakko	FX-600
2	Solder		
3	Flux		
4	Sewing needle		
5	Toothpick		
3	Toilet paper		
4	Rubbing alcohol		
5	Hot glue gun	PAM	HB220
6	Hot glue adhesive sticks	PAM	UX8012
7	Multimeter		
	Headband magnifier, 2.75X magnification, 6-inch focal length, glass lens plate	Donegan	DA-7 OptiVisor
	Needle files		
	Needle nose pliers		

4. ASSEMBLY INSTRUCTIONS.

4.1. Solder resistor to connector.

The following steps explain how to solder the resistor to the connector. Make two of these, one for each reed plate on the harmonica. Wear a 2.75X headband magnifier as required.

Step 1. -- Use a pair of needle nose pliers to bend the pins of the connector outwards and then downwards so they are just barely touching the solder terminals on the resistor. It is okay if there is a small gap between the ends of the pins and the solder terminals on the resistor because the molten solder will bridge the gap.

Step 2. -- Put a small piece of toilet paper (about 1 cm by 1 cm) in the connector and wet it with a few drops of water. Ensure that the wet toilet paper is making good contact with the pins inside the connector. This will prevent the plastic housing of the connector from melting when heat is applied to the contacts (pins) of the connector during the soldering operation.

Step 3. -- Use the tip of a sewing needle to apply a tiny amount of flux to the terminals on the resistor and to the pins on the connector.

Step 4. -- Tin the pins on the connector by heating them up with the soldering iron and applying just enough solder to coat the ends of the pins. If you hear a sizzling noise from the wet toilet paper, stop and remove the heat from the pins so you don't melt the connector housing.

Step 5. -- Tape the connector to a scrap piece of wood so the pins are lined up with the resistor. The tape ensures that the connector won't move during the soldering operation. The resistor must be placed with the white (ceramic) side down, and the black (resistive film) side up.

IMPORTANT: Do not damage the black (resistive film) side of the resistor. If the resistive film is damaged, then the resistance value will probably increase and you will get less heat from the resistor.

Step 6. -- Solder the resistor to the pins of the connector. If you hear a sizzling noise from the wet toilet paper, stop and remove the heat from the pins so you don't melt the connector housing.

Step 7. -- Remove the wet toilet paper from the connector.

Step 8. -- Clean the connector and resistor with rubbing alcohol applied to a small piece of toilet paper to remove the flux residue from the soldering operation. Notice that the toilet paper doesn't fall apart easily when it is soaked with rubbing alcohol like it would if it was soaked with water.

Step 9. -- Measure the resistance between the two pins of the connector and ensure that it is equal to the value of the resistor (for example, 39.9 ohms).

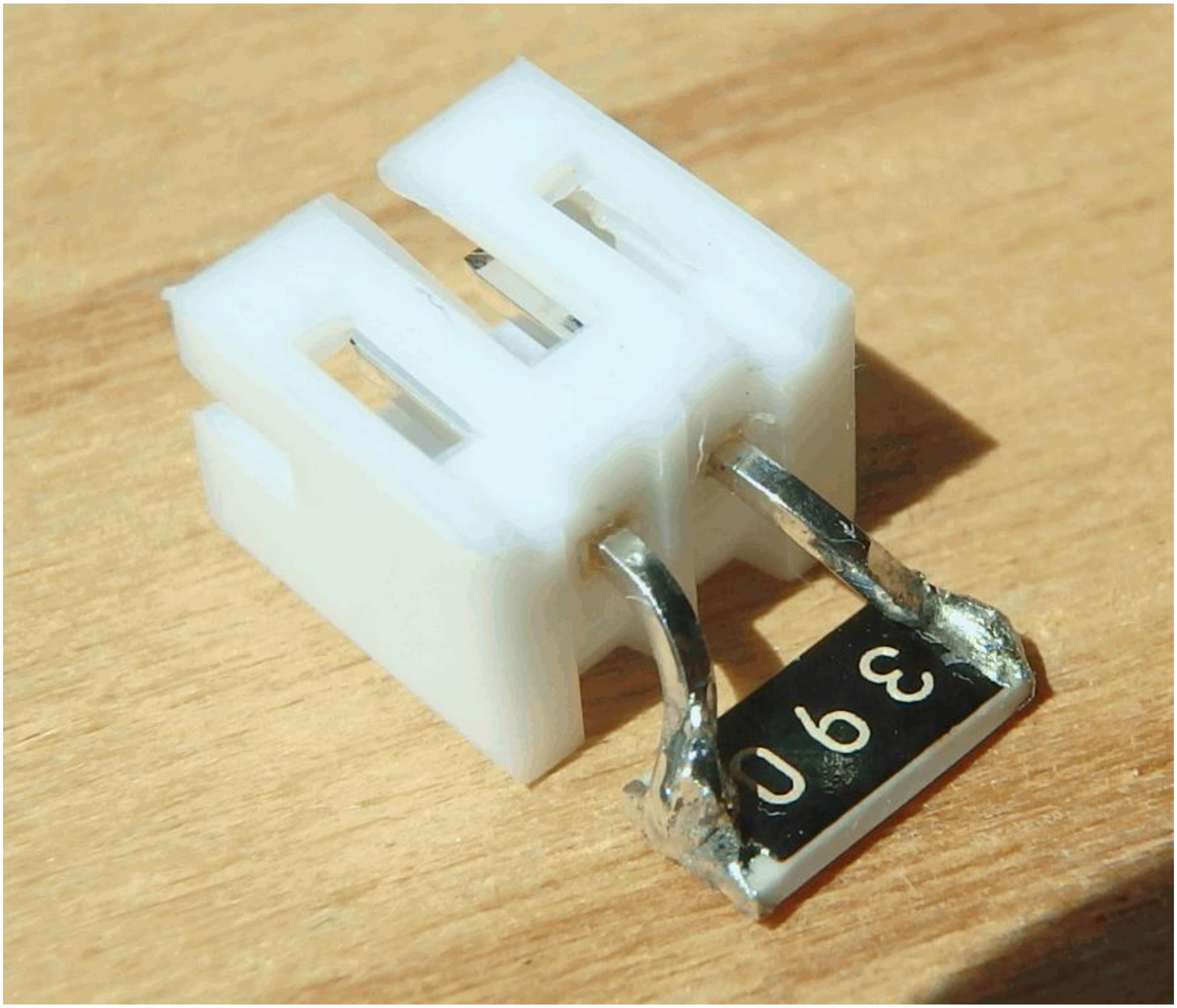


Figure 4-1. Resistor soldered to connector.

4.2. Remove harmonica covers.

Remove the covers from the harmonica. Do not remove the reed plates, mouthpiece, and slide.

4.3. Glue resistor and connector to reed plate.

Glue the resistor on the outside edge of the reed plate, near the middle of the harmonica, with J-B Weld epoxy.

Step 1. -- Clean the reed plates with rubbing alcohol applied to a small piece of toilet paper. This removes any grease so the epoxy will adhere more strongly.

Step 2. -- Mix the epoxy with a toothpick and apply enough to cover the bottom (white ceramic side) of the resistor and the bottom of the connector. It is better to apply a little too much epoxy because you don't want the resistor terminals to be directly touching the reed plate.

IMPORTANT: It is very important for there to be some epoxy between the resistor terminals and the reed plate. If the resistor terminals are in direct contact with the reed plate, then the reed plate will short out the resistor and it will not provide any heat. Also, the USB power supply or battery will not be very happy if the resistor is shorted out.

Step 3. -- Place one connector and resistor on one of the reed plates and allow the epoxy to cure for a few hours. Place any extra epoxy that you mixed in the freezer to delay it from curing. Epoxy will keep for eight or more hours in the freezer without curing significantly.

Step 4. -- Glue the second connector on the other reed plate using freshly mixed epoxy or the leftover epoxy that was in the freezer.

Step 5. -- Allow the epoxy to fully cure (overnight).

Step 6. -- Apply more epoxy to fully cover the resistor and exposed pins of the connector. Also reinforce the sides of the connector slightly.

Step 7. -- Allow the epoxy to fully cure (overnight).

Step 8. -- Measure the resistance between the two pins of the connector using a multimeter. It should be equal to the value of the resistor (for example, 39.9 ohms).

Step 9. -- Measure the resistance between each pin of the connector and the reed plate to ensure that the resistor terminals are not shorted to the reed plate. It should measure as an "open circuit", meaning that the resistance is very high.

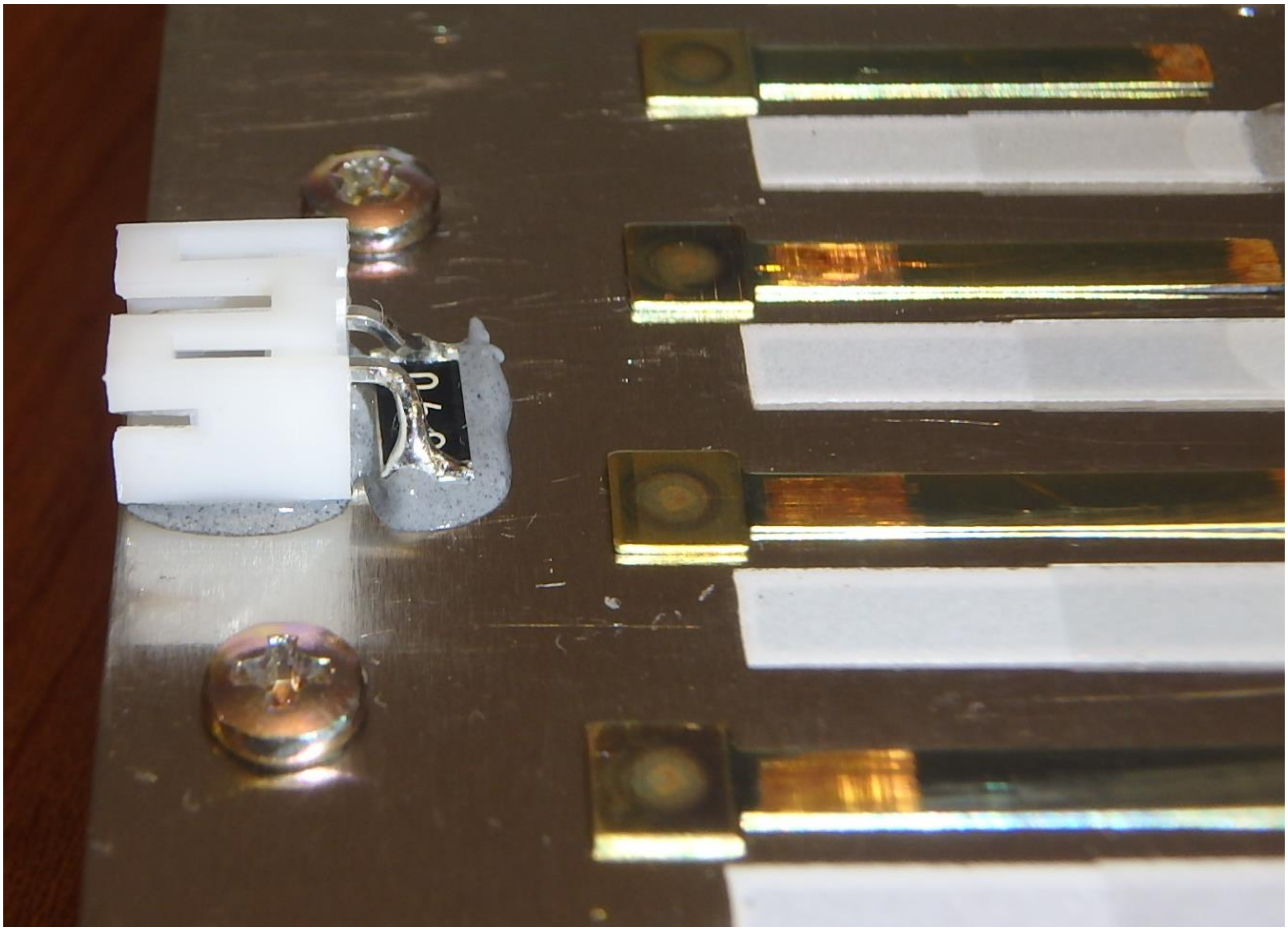


Figure 4-2. Heater glued to reed plate, side view.

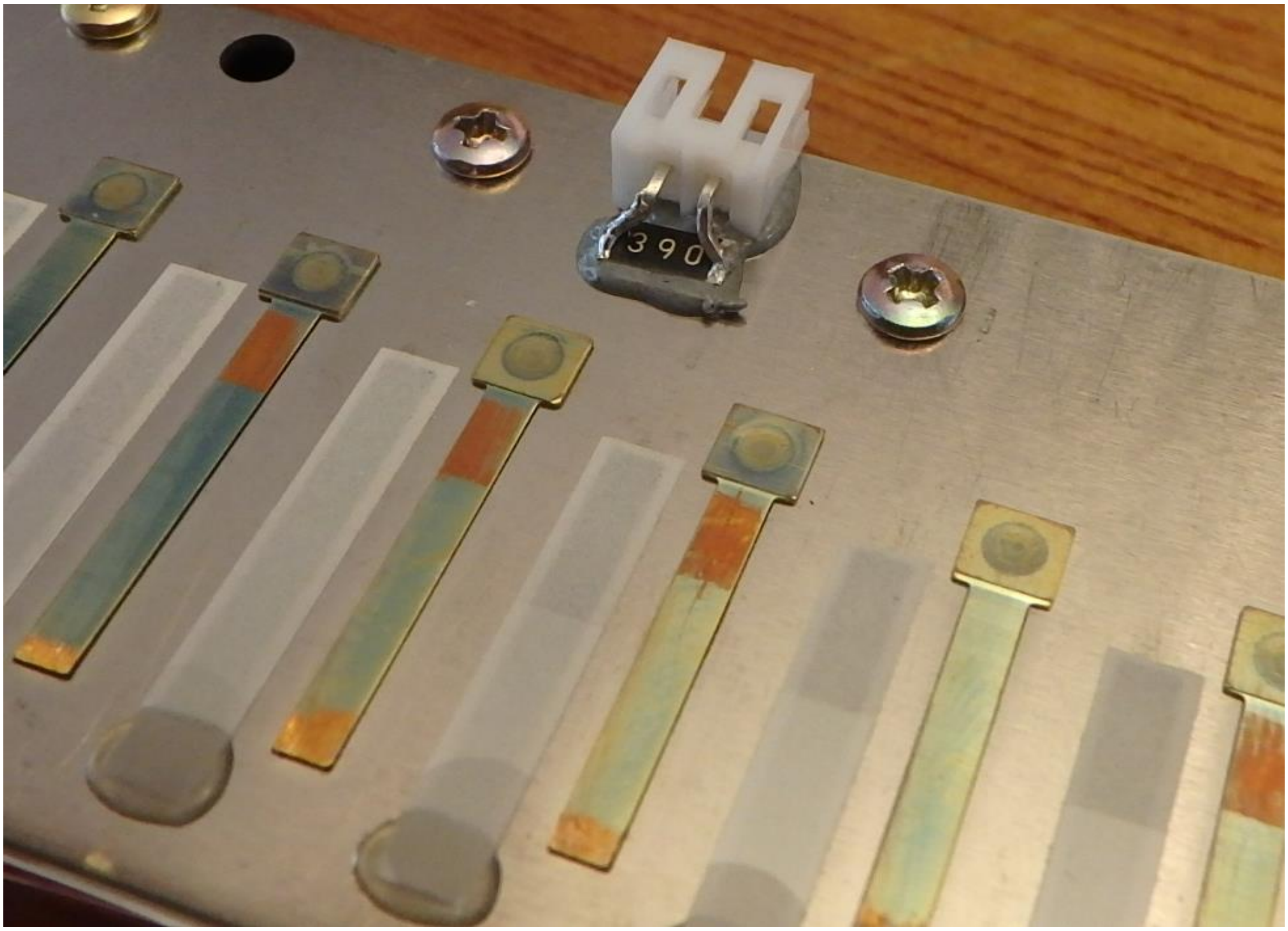


Figure 4-3. Heater glued to reed plate, rear view.

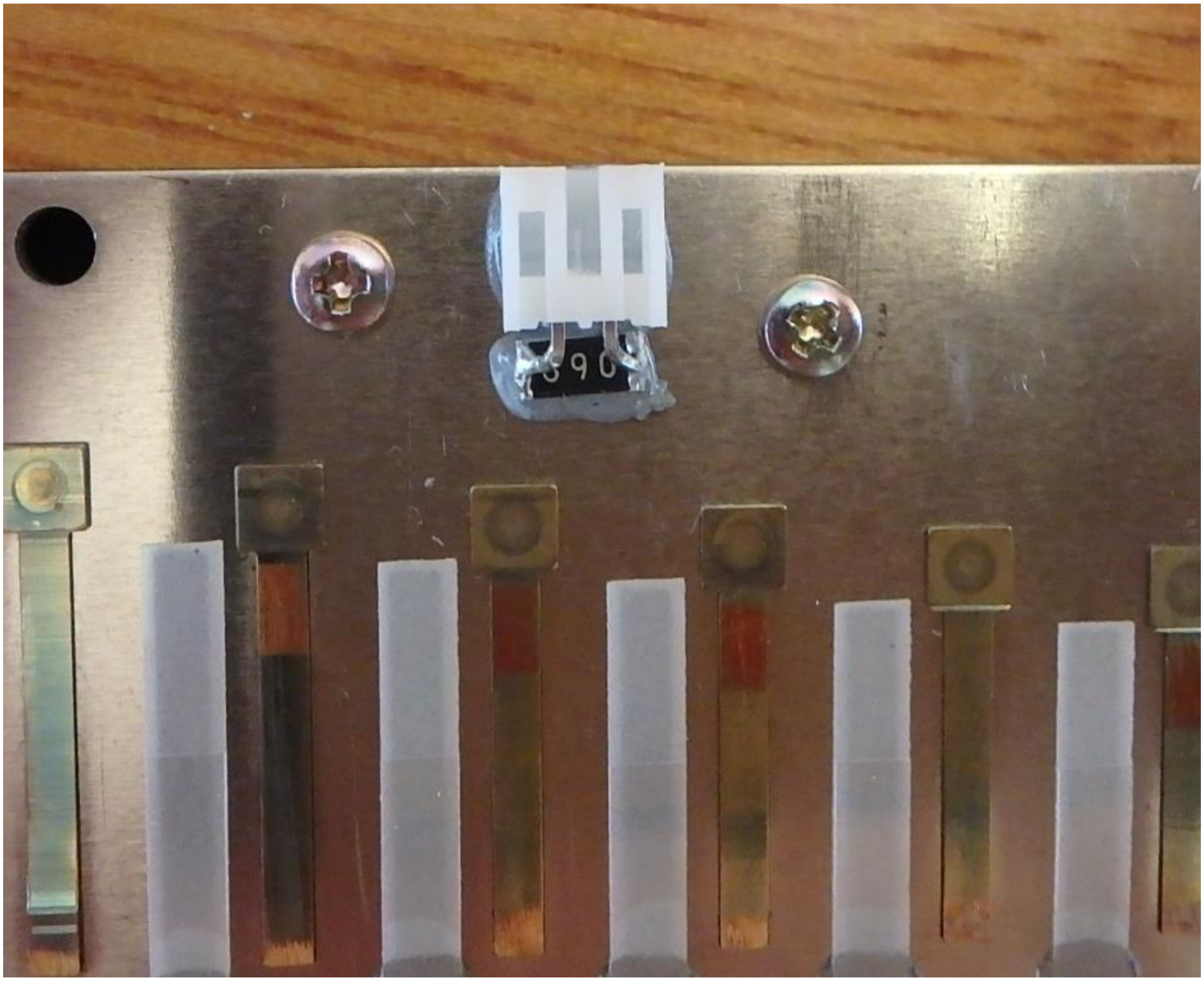


Figure 4-4. Heater glued to reed plate, top view.

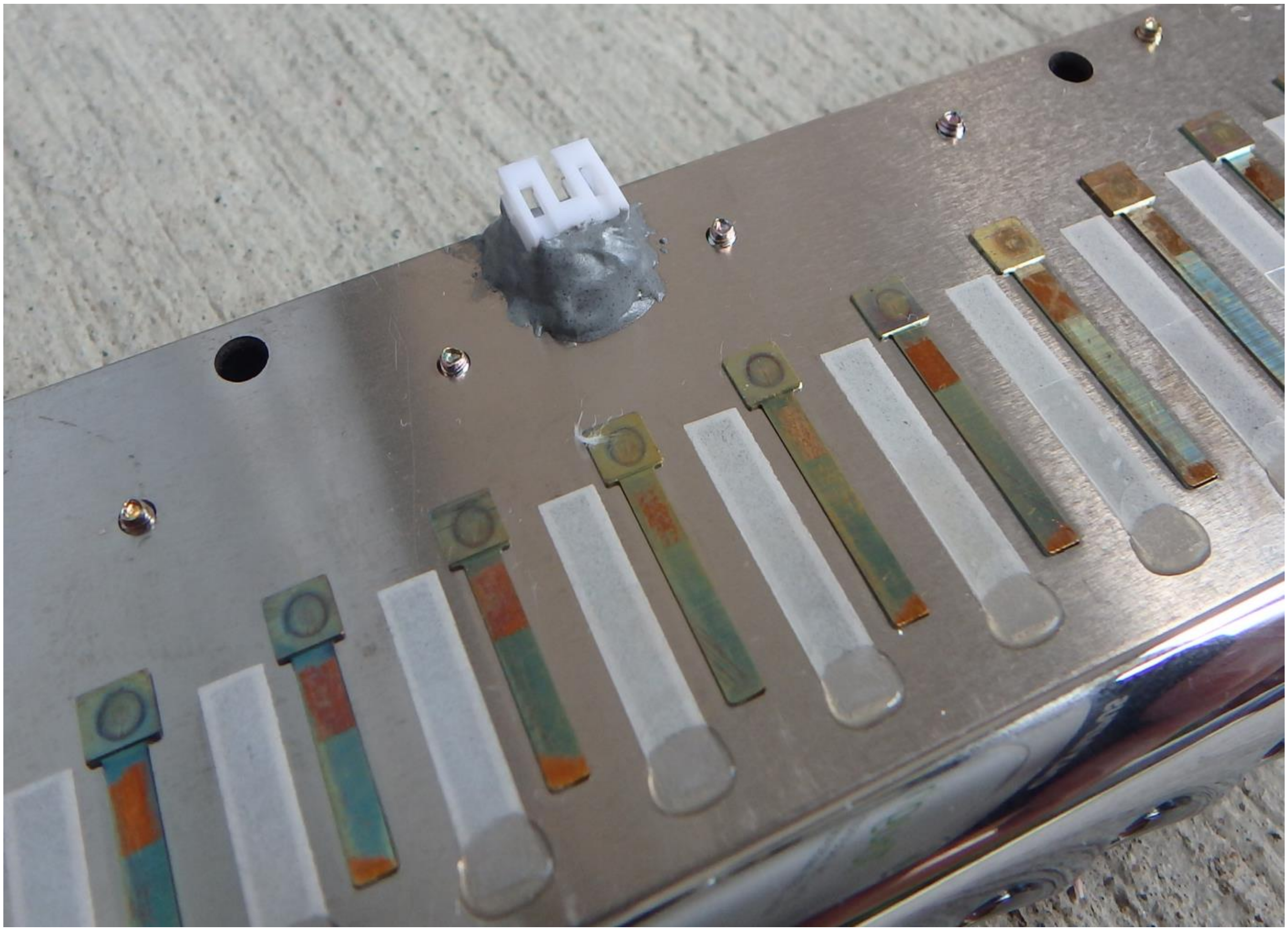


Figure 4-5. Resistor fully encased in epoxy.

4.4. Modify harmonica covers.

4.4.1. Suzuki Chromatix.

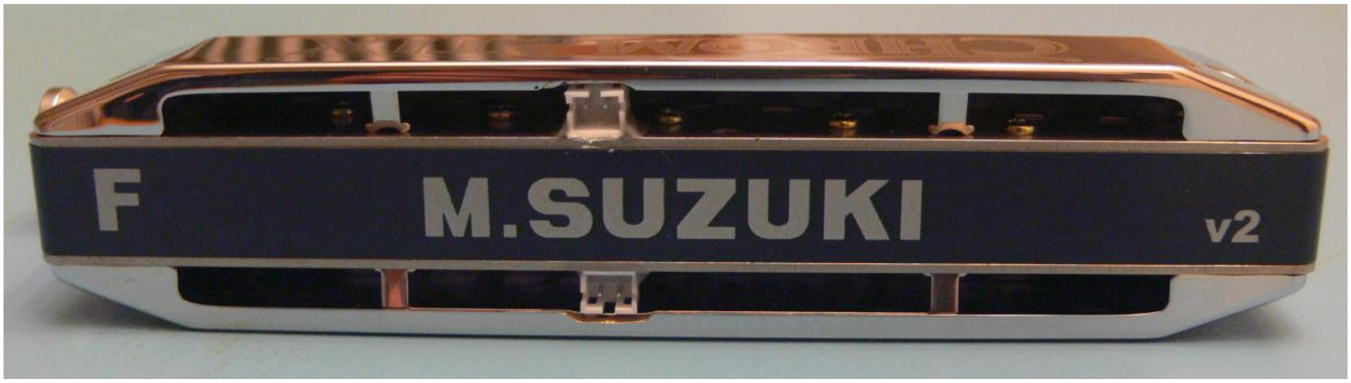


Figure 4-6. Suzuki Chromatix SCX 48 with PEHW 1-1.

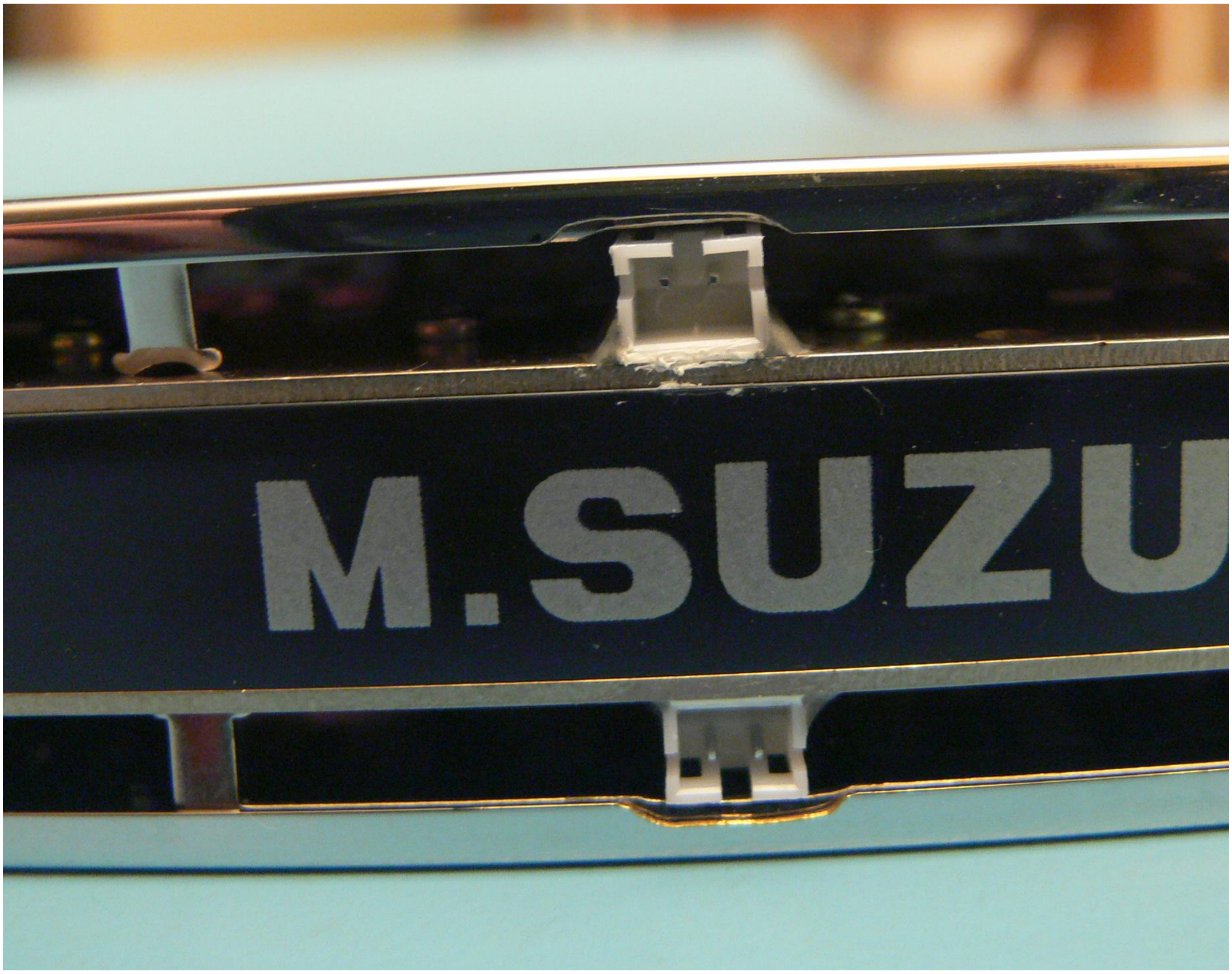


Figure 4-7. Suzuki Chromatix SCX 48 closeup view.

4.4.2. Hohner CX-12.

The outer plastic cover of the Hohner CX-12 does not need to be modified, but the spring tension bar that holds the comb in place does need to be modified.

4.5. Modify USB cable.

USB cable. -- There are four flavours of USB. Avoid using a SuperSpeed USB 3.x cable because it has 10 wires and you only need to use the two power wires. The USB 2.0 cable consists of 4 wires. The power wires are the two un-twisted red and black wires. The red wire is +5 volts and the black wire is ground (0 volts). The USB 2.0 specification states that the power wires can be between 28 AWG (thin wire) and 20 AWG (thick wire). If you have a choice, it is best to use a cable that has the 20 AWG wire.

Table 4-1. USB flavours.

	Description	Data Rate	USB Specification	Cable Type
1	Low Speed USB	1,500,000 bits/second	USB 1.x	4 wires
2	Full Speed USB	12,000,000 bits/second	USB 1.x USB 2.0	4 wires
3	High Speed USB	480,000,000 bits/second	USB 2.0	4 wires
4	SuperSpeed USB	5,000,000,000 bits/second	USB 3.x	10 wires

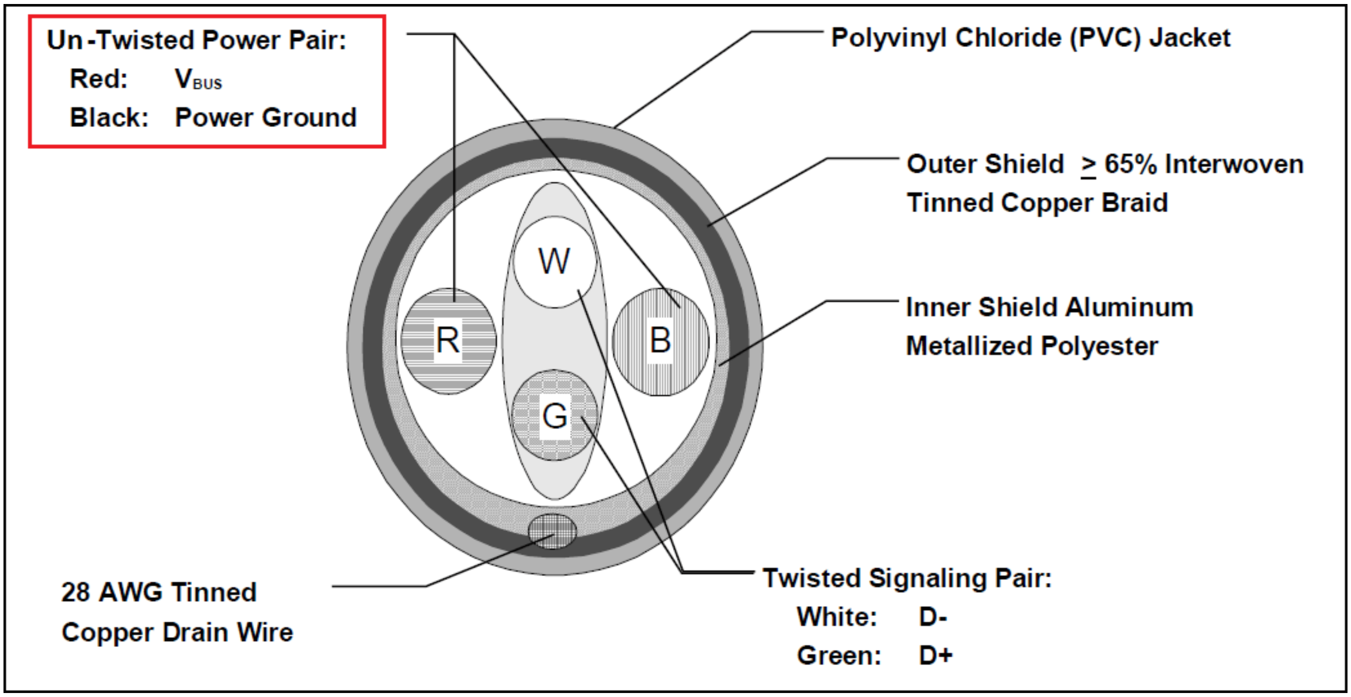

Un-Twisted Power Pair:
Red: V_{BUS}
Black: Power Ground
Polyvinyl Chloride (PVC) Jacket
Outer Shield ≥ 65% Interwoven Tinned Copper Braid
Inner Shield Aluminum Metallized Polyester
W
R
B
G
28 AWG Tinned Copper Drain Wire
Twisted Signaling Pair:
White: D-
Green: D+

Figure 4-8. USB 2.0 cable.

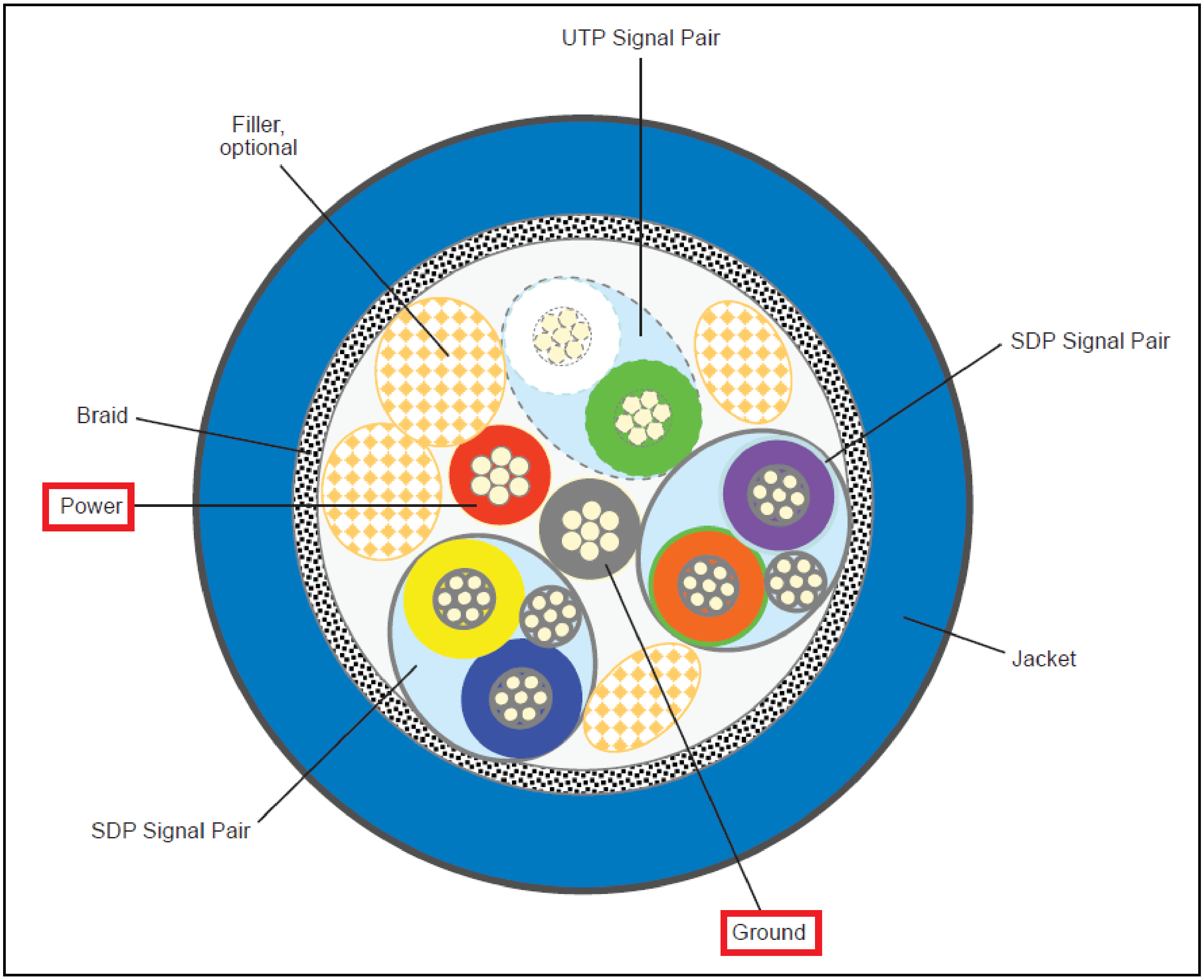


Figure 4-9. USB 3.0 cable.

JST PH connectors. -- The JST PH 2-mm pitch top-entry through-hole header connectors can be found on Amazon with the mating housing that includes the contacts with red and black wires attached that need to be soldered to the red and black wires in the USB cable.

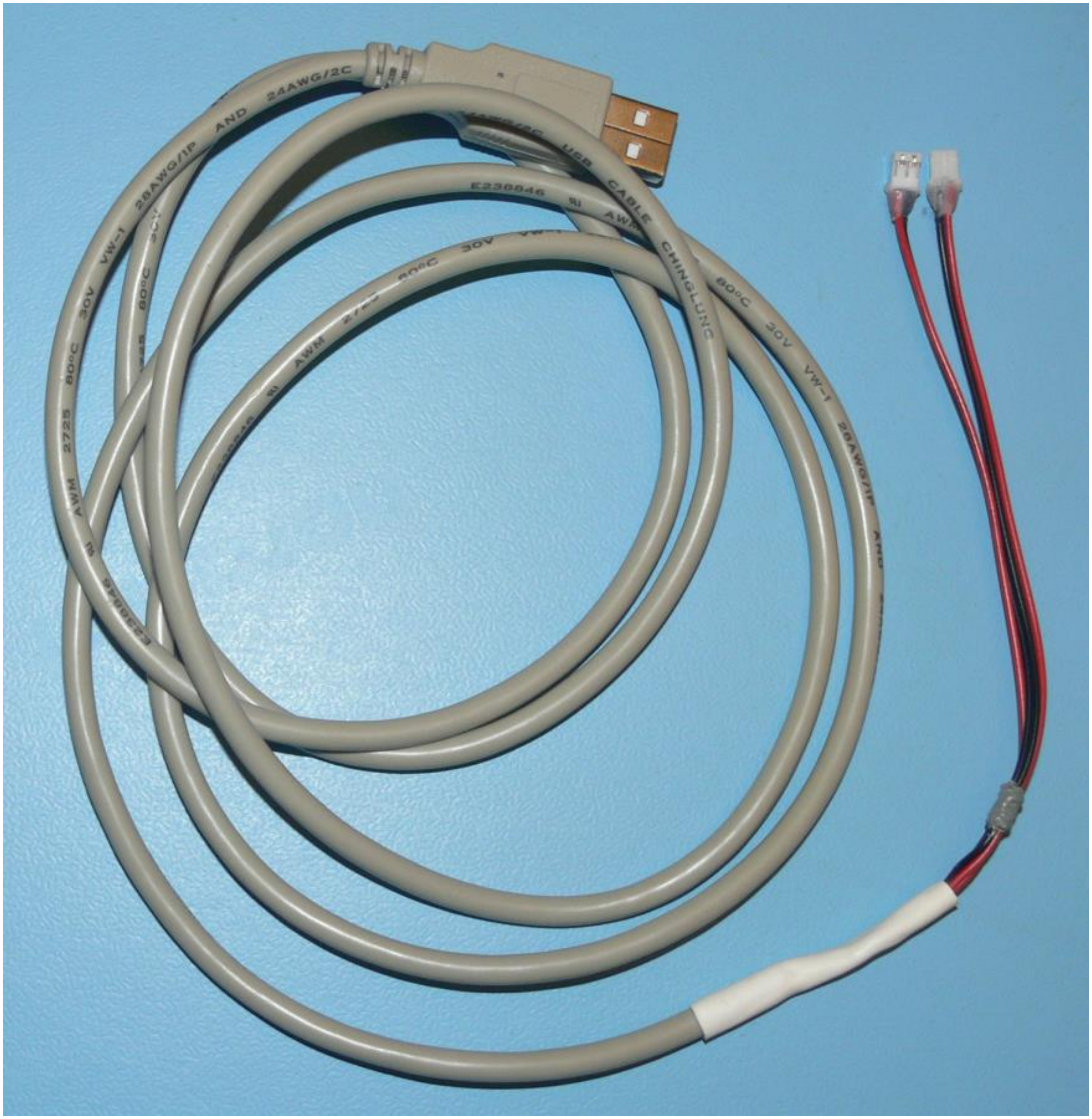


Figure 4-10. Modified USB cable.

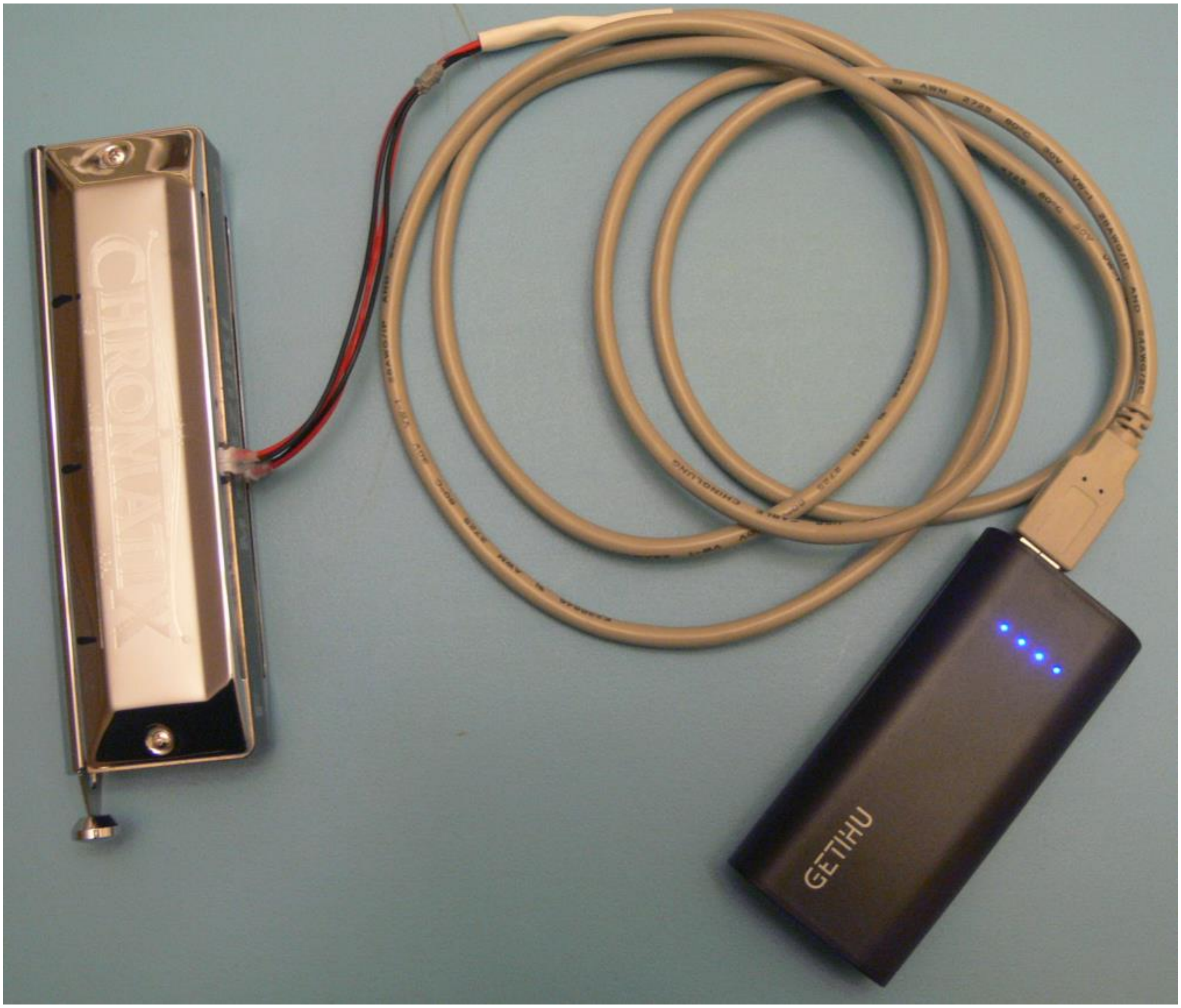


Figure 4-11. Harmonica, cable, and battery.

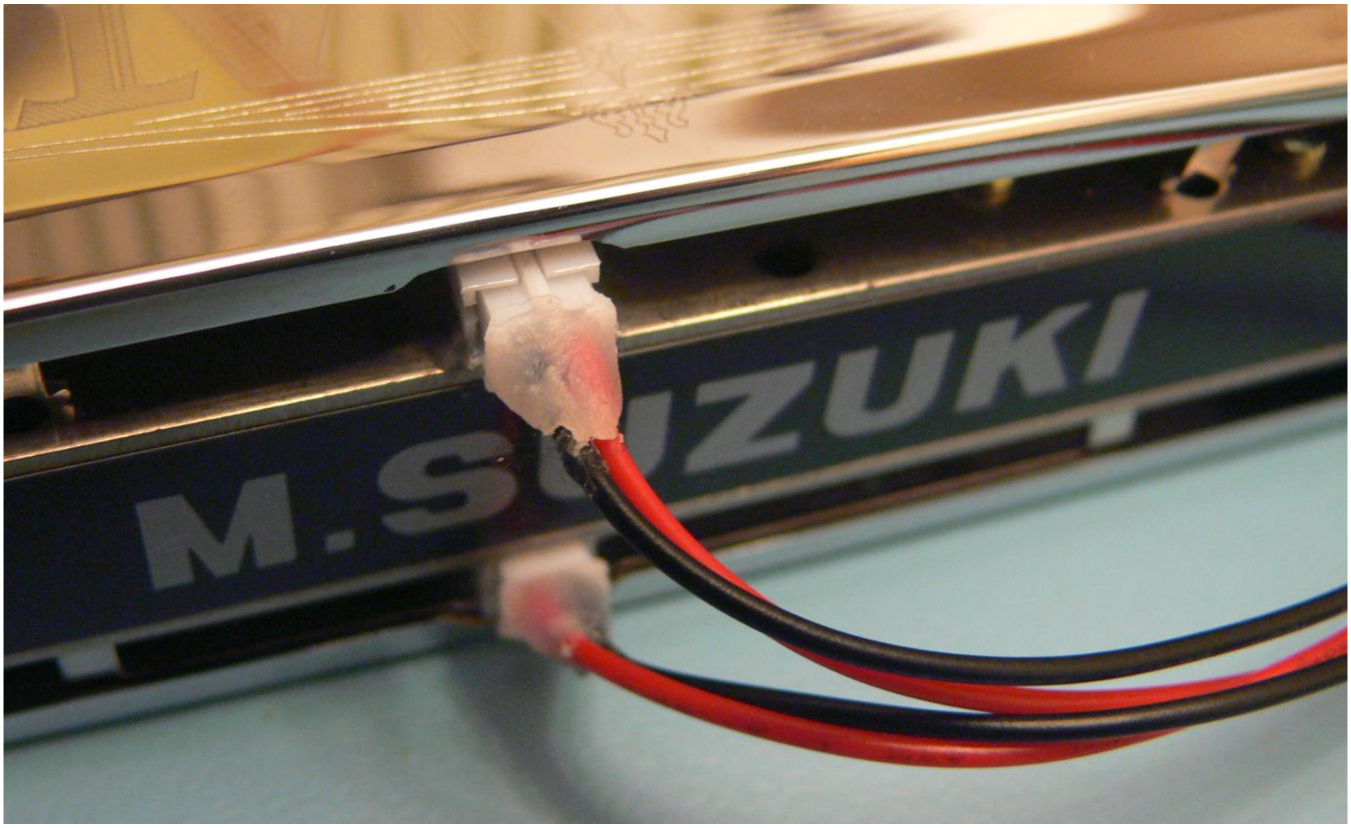


Figure 4-12. Harmonica and cable closeup view.

5. FUTURE IMPROVEMENTS.

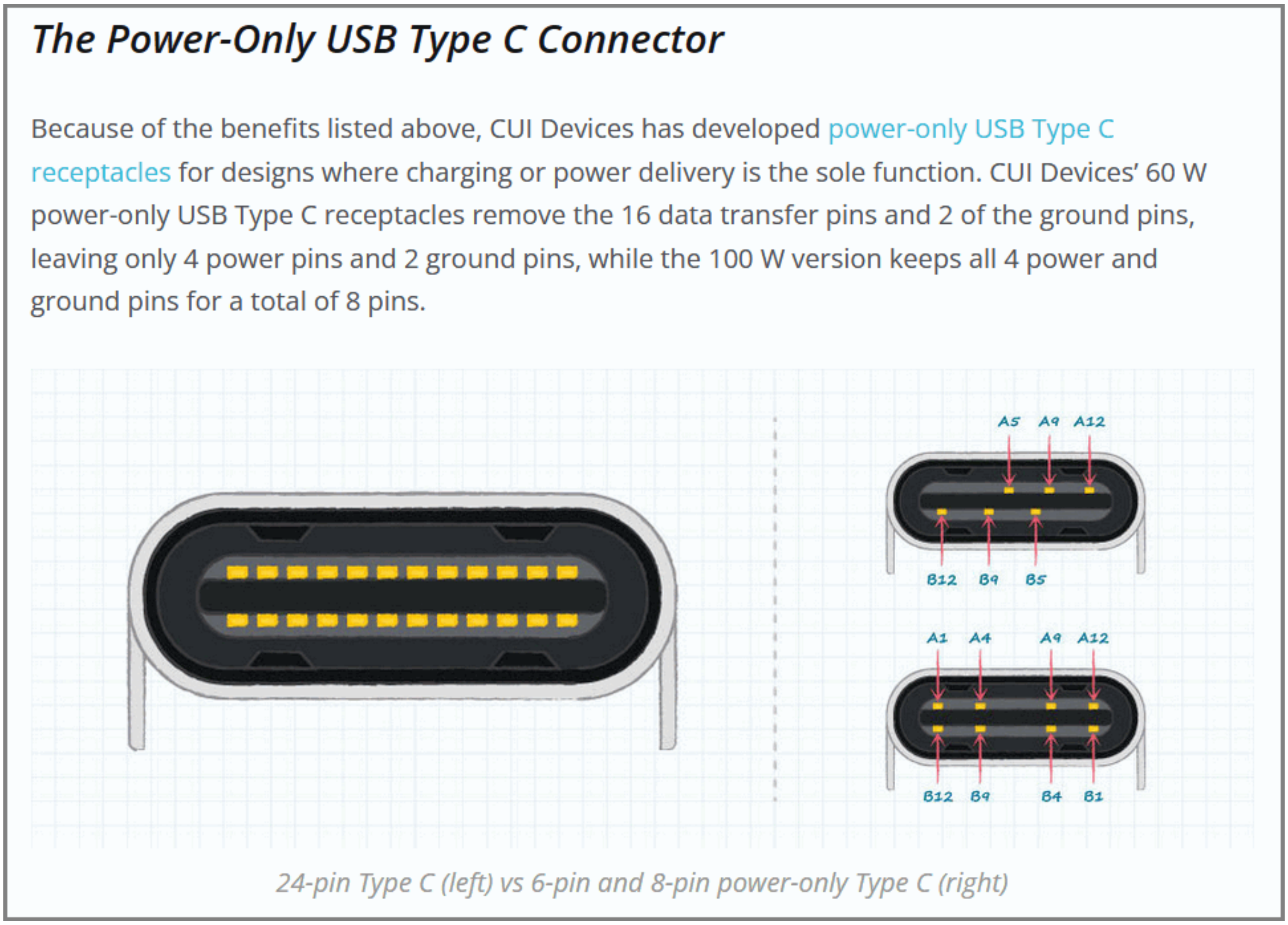
5.1. Connector.

A lower profile connector would be better.

A micro USB connector would be good because then a standard USB cable could be used without any modifications.

You could make a short adapter cable that plugs into the harmonica with a micro USB connector that can then plug into a standard USB charging cable.

5.1.1. USB-C connector.



The Power-Only USB Type C Connector

Because of the benefits listed above, CUI Devices has developed power-only USB Type C receptacles for designs where charging or power delivery is the sole function. CUI Devices' 60 W power-only USB Type C receptacles remove the 16 data transfer pins and 2 of the ground pins, leaving only 4 power pins and 2 ground pins, while the 100 W version keeps all 4 power and ground pins for a total of 8 pins.

24-pin Type C (left) vs 6-pin and 8-pin power-only Type C (right)

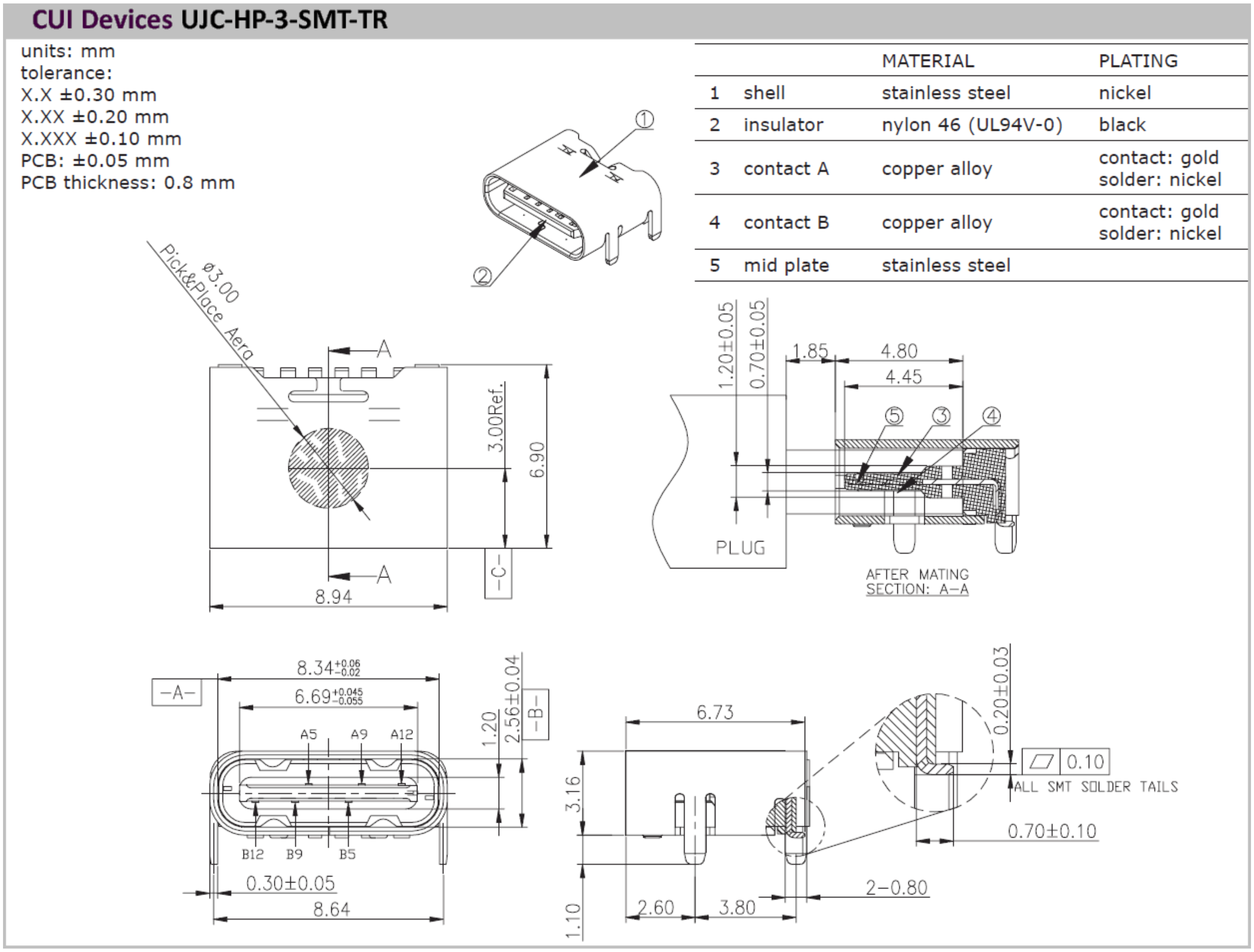
The gap at the back of the harmonica between the cover and the reed plate is 0.180 inches. Mount the USB-C connector on top of a PWB with the resistor on the bottom side of the PWB. The resistor should be solder on "upside down" with the film side against the PWB and the ceramic base on the outside so it will be closer to the harmonica's reed plate.

0.124"	USB-C connector height (3.16 mm)
0.020"	PWB thickness
0.020"	Resistor thickness
0.164"	TOTAL thickness

A total thickness of 0.164 inches allows up to 0.016 inches of epoxy between the resistor and the harmonica's reed plate. If this isn't enough, the harmonica's cover can be filed to remove some metal and increase the gap.

CUI Devices mid-mount 6-pin USB-C connector: UJC-HP-M-G-5-MSMT-TR

CUI Devices surface mount 6-pin USB-C connector: UJC-HP-3-SMT-TR



CUI Devices **UJC-HP-3-SMT-TR**

units: mm
tolerance:
X.X ±0.30 mm
X.XX ±0.20 mm
X.XXX ±0.10 mm
PCB: ±0.05 mm
PCB thickness: 0.8 mm

		MATERIAL	PLATING
1	shell	stainless steel	nickel
2	insulator	nylon 46 (UL94V-0)	black
3	contact A	copper alloy	contact: gold solder: nickel
4	contact B	copper alloy	contact: gold solder: nickel
5	mid plate	stainless steel	

5.2. Conformal coating.

MG Chemicals 422C.